#4



PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Anne-Marie GESRET, et al.

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Confirmation No.: 3303 | Examiner: Unknown

Filed: March 9, 2001

For: METHOD FOR ACQUISITION OF SLOT TIMING A DIRECT SEQUENCE SPREAD SPECTRUM COMMUNICATION RECEIVER

## SUBMISSION OF PRIORITY DOCUMENT

Commissioner for Patents
Washington, D.C. 20231

Sir:

Submitted herewith is a certified copy of the priority document on which a claim to priority was made under 35 U.S.C. § 119. The Examiner is respectfully requested to acknowledge receipt of said priority document.

Respectfully submitted,

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GB0006191.1

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[ADP No. 08062325001]

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1. Your reference 3919

16MAR00 E521469-1 D03086
F01/7700 0.00-0006191.1

2. Patent application number *(The Patent Office will fill in this part)* 0006191.1 14 MAR 2000

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

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Patents ADP number *(if you know it)* 7013303001

SECTION 30 (1977 ACT) APPLICATION FILED 5.10.00

If the applicant is a corporate body, give the country/state of its incorporation ENGLAND AND WALES

4. Title of the invention METHOD FOR ACQUISITION OF SLOT TIMING IN A DIRECT SEQUENCE SPREAD SPECTRUM COMMUNICATION RECEIVER

5. Name of your agent *(if you have one)*

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Patents ADP number *(if you know it)* ~~7406027001~~ 7336555001

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# Method for acquisition of slot timing in a direct sequence spread spectrum communication receiver.

This invention relates to a direct sequence spread spectrum communication receiver and in particular it relates to a method for acquisition of slot timing during initial cell search synchronization.

When power is applied to a mobile station the task of synchronization with a base station is initiated (initial cell search). The characteristics of the Universal Mobile Telecommunications System (UMTS) and the procedure for initial cell search to which the following description relates is described in the European Telecommunications Standards Institute (ETSI) publication TR 101 146 version 3.0.0 Universal Mobile Telecommunications System, Concept evaluation. As will be clear to those skilled in the art the instant invention is not restricted to use with the UMTS and may also be applied to other WCDMA systems. Reference is made to US 5 982 809 to Liu which forms part of the prior art.

The initial cell search by the mobile station is performed in three steps and the first step is the acquisition of slot synchronization to the transmissions of the base station providing, through a fading path, the strongest signal at the receiver of the mobile station. With reference to figure 1 which is a schematic illustration of base station broadcast transmissions, base station transmissions are represented at 1, the transmission channel at 2 and the mobile station receiver at 3. In figure 1 by way of example the transmissions from only two base stations (BTS1 and BTS2) are shown.

These base station transmissions are not synchronized with each other and are maintained to transmit over common fixed duration time intervals referred to as slots and common fixed duration framing intervals referred to as frames. One frame comprises 15 slots. In figure 1 the start of a slot for the transmissions from BTS 2 is shown delayed from the start of a slot for the transmissions from BTS1 by an arbitrary amount 't' seconds.

The base station transmissions include a synchronization channel (SCH) aligned with the slot boundary and a primary common control physical channel (PCCPCH). The synchronization channel comprises a primary synchronization code (PSC) and a secondary synchronization code (SSC) as illustrated in figure 2. The code transmitted as the primary synchronization code (Cp) is repeated at the beginning of each slot by all base stations.

The BTS transmissions to the receiver 3 will be affected by channel 2 and the transmissions of BTS 2 are illustrated as received through a 3-path (multipath) channel while the transmissions of BTS1 are illustrated as received through a 2-path channel. The signals from BTS 1 and BTS2 are effectively summed in channel 2 before arriving at receiver 3. Correlation of the received signal with the expected primary synchronization code which is stored in the receiver provides a number of correlation peaks. The highest peak detected corresponds to that base station of the network (the found base station) to which the receiver will synchronize.

The second step of initial cell search establishes frame synchronization and identifies the code group of the base station found in step 1 (the found base station). The third step of initial cell search determines the scrambling code assigned to the found BS.

A correlation process is performed sample-by-sample and over one slot. The number of shifts of the input data used is the product of the number of chips per slot and the oversampling rate (OSR). The results of the correlation process are averaged over a number of slots and the position of the sample with highest correlation power is selected as the slot boundary.
The number of slots used in the averaging process is referred to as the averaging depth.

It is possible also to select and store the positions of the largest peaks from the number of peaks found in the first step. This information can then be used for the remaining two steps to determine the best slot-timing when one detected peak is selected but does not provide satisfactory results in the 2nd and/or the 3rd steps. In such a case, other peaks detected in the 1st step may be selected and used in the 2nd and 3rd steps.

Pipelining methods are known whereby different cell search steps operate on different parts of the received data (input blocks). The sizes of the input buffer required depends upon the averaging depth of the individual steps. For an averaging depth of one frame per step, the required buffer size is equal to one frame of data.

The provision of some sort of memory storage is germane to the cell search process. Satisfactory performance of the 2nd and 3rd steps depends upon satisfactory performance previously of the 1st and 2nd steps. When using the same (or part of the same) data portion with all three steps and if averaging is applied to various steps the required memory size increases. Application of averaging to the 1st step is necessary due to the variations in channel conditions. In order to obtain a reliable slot-timing approximation, it would usually be necessary to implement averaging over a number of slots. Averaging may also be applied (over a number of frames) to the 2nd and 3rd steps.

To obtain the slot-timing, the minimum required input data length for the 1st step, corresponding to correlation of a single slot with the (PSC) is [(CHIPS_PER_SLOT + CHIPS_PER_SYMBOL) x OSR – 1]. The number of chips per time slot is expressed as chips_per_slot and the number of chips per symbol as chips_per_symbol. As synchronization for the 2nd step is based on a codeword which is transmitted over one frame, one frame of input data samples for the second step is envisaged. Similarly one frame of input data samples for the 3rd step would accommodate the periodic transmission of the scrambling codes.

With all three steps operating on the same data block and assuming an averaging depth of 15 slots (i.e. 1 frame) for the first step, an input data buffer for the cell search process will need to store 38656xOSR-1 complex samples. For an OSR = 4 and using 8 bits per I (in phase) and 8 bits per Q (quadrature) component of each input sample, the required buffer size will be found as

309246 bytes. The memory size would of course increase further if averaging depths of more than 1 frame were applied to steps 2 and/or 3. A buffer size sufficient to accommodate at least 2 frames of data , i.e. 614400 bytes would be more likely.

It is an object of the invention to provide efficient methods for implementing initial cell search in a WCDMA system which reduce significantly the size of input buffers.

According to the invention there is provided a method of acquiring slot timing when synchronizing a direct sequence spread spectrum communications receiver with the transmissions of a network base station comprising repetitive correlation of a synchronization code received over a radio channel with a synchronization code stored in the receiver and at each repetitive correlation assigning a value to resulting peaks, ranking the peaks according to the assigned values and selecting the peaks with the highest ranking for slot timing.

An example of the invention will now be described with reference to the accompanying figures in which:

figure 1 is a schematic illustration of base station transmissions,

figure 2 illustrates the composition of base station transmissions,

figure 3 is a flow chart illustrating the method of slot synchronization,

table 1 is an example of peak buffer content,

table 2 shows information in table 1 rearranged according to the peak positions,

table 3a is an example of peak buffer content including age factor,

table 3b shows information in table 3a rearranged according to the peak positions.

The memory requirements for the first step of the cell search process can be reduced significantly if the correlation peaks are selected on slot-by-slot basis rather than after a number of slots. The need to obtain an average over a number of slots when selecting the correlation peaks remains, however and must be reconciled in any method to be implemented. The method described herein satisfies the requirement for averaging whilst reducing significantly the amount of memory required.

Further details will be given with reference to figure 3 where a flow chart descriptive of the method of the present invention is shown. The PSC data received in the first slot is correlated with the PSC stored in the receiver and the maximum peaks arising from the correlation are selected and saved in a buffer (a peak buffer). The maximum peaks arising from the correlations with successive slots are found also and saved in a separate peak buffers in a similar manner. The number of peak buffers used is equal to the averaging depth for the $1^{st}$ step.

The information saved in each peak buffer, in respect of each peak resulting from a correlation is a value comprising a set of numbers. One number in the set of numbers is assigned as the order of the peak. The highest peak saved to a peak buffer is assigned the highest order, the second highest peak is assigned the second highest order *et seq*. The weakest element of each buffer is assigned the lowest order 1.

One number in the set of numbers is assigned as the power of the peak. This is derived by the addition of the squared correlation result obtained for the I component to the squared correlation result obtained for the Q component. One number in the set of numbers is the position of the peak within the slot, which is the position [modulo(chips_per_slot x OSR)+1] of the input data with which the PSC is aligned for the correlation generating that peak. For each received slot, the alignment with the first received sample corresponds to position 1 and the alignment with the last sample of the slot is position chips_per_slot x OSR.

With reference to tables 1 and 2 , when all of the peak buffers have been filled, the saved information corresponding to the peaks is re-arranged in accordance with the positions of the peaks. A parameter, which we shall call M, is computed for each position. The value of M for any position depends upon the order and the power of the peak at that position such that $M = \sum(\text{power x order})$. The peaks corresponding to the largest values of M are selected as the output of the first step. The example given in tables 1 and 2 has the number of peaks detected in the correlation as 3 and the averaging

depth of the 1st step is 3. The contents of the three peak buffers are shown in table 1.

The data saved in the three peak buffers are re-arranged in accordance with the position of each peak. It will be seen from table 2 that the positions corresponding to the three largest values of M are positions 2, 10 and 50. These positions are returned as the output of the first step. The age of each peak buffer may also to be taken into account when the parameter M is computed. An additional weighting factor decreasing with the age of each buffer may be included when the parameter M is determined.
With the inclusion of the additional weighting factor (age_factor ) the parameter M will be obtained as $M=\Sigma$(power x order x age_factor).

With reference to tables 3a and 3b an example is shown for obtaining a value of M when the age factor is taken into account. In this example the age factor assigned to the first peak buffer is unity, for the second peak buffer 0.5 and for the third peak buffer 0.25.

Although with these methods, the buffer size depends on the number of desired peaks and the averaging depth used, it will be significantly less than is required for existing prior art methods.

## Claims

1. A method of acquiring slot timing when synchronizing a direct sequence spread spectrum communications receiver with the transmissions of a network base station comprising repetitive correlation of a synchronization code received over a radio channel with a synchronization code stored in the receiver and at each repetitive correlation assigning a value to resulting peaks, ranking the peaks according to the assigned values and selecting the peaks with the highest ranking for slot timing.

2. A method as in claim 1 in which the said value is assigned as a set of numbers and in which each number in the set of numbers corresponds to a measured parameter of the resulting peaks.

3. A method as in claim 2 in which one number in the set of numbers corresponds to the power of a resulting peak.

4. A method as in claims 2 and 3 in which one number in the set of numbers corresponds to the position of a resulting peak.

5. A method as in claims 2 to 4 in which one number in the set of numbers corresponds to the order of a resulting peak.

6. A method as in any preceding claim in which the ranking parameter is computed from a subset of the assigned values.

7. A method as in claim 6 in which the ranking parameter is computed as the sum of the product of the assigned values for power and for order.

8. A method as in claims 1 to 5 in which the ranking parameter is derived from a subset of the assigned values and an additional factor.

9. A method as in claim 8 in which the additional factor is age.

10. A method as in claim 8 in which the ranking parameter is computed as the sum of the product of the assigned values for power, the assigned values for order and the additional factor for age.

# Abstract

Method for acquisition of slot timing in a direct sequence spread spectrum communication receiver.

A set of values corresponding to measured parameters of the output peaks resulting from the correlation of the received data with a synchronization code stored in the receiver are saved to a buffer. Subsequent transmissions of the synchronization data are similarly correlated in the receiver and the results stored as assigned values in further buffers. The contents of the buffers are then regrouped according to their positional entries. A ranking is computed from the values assigned for each position and the positions with the highest ranking are selected for slot timing.

(Fig 3)

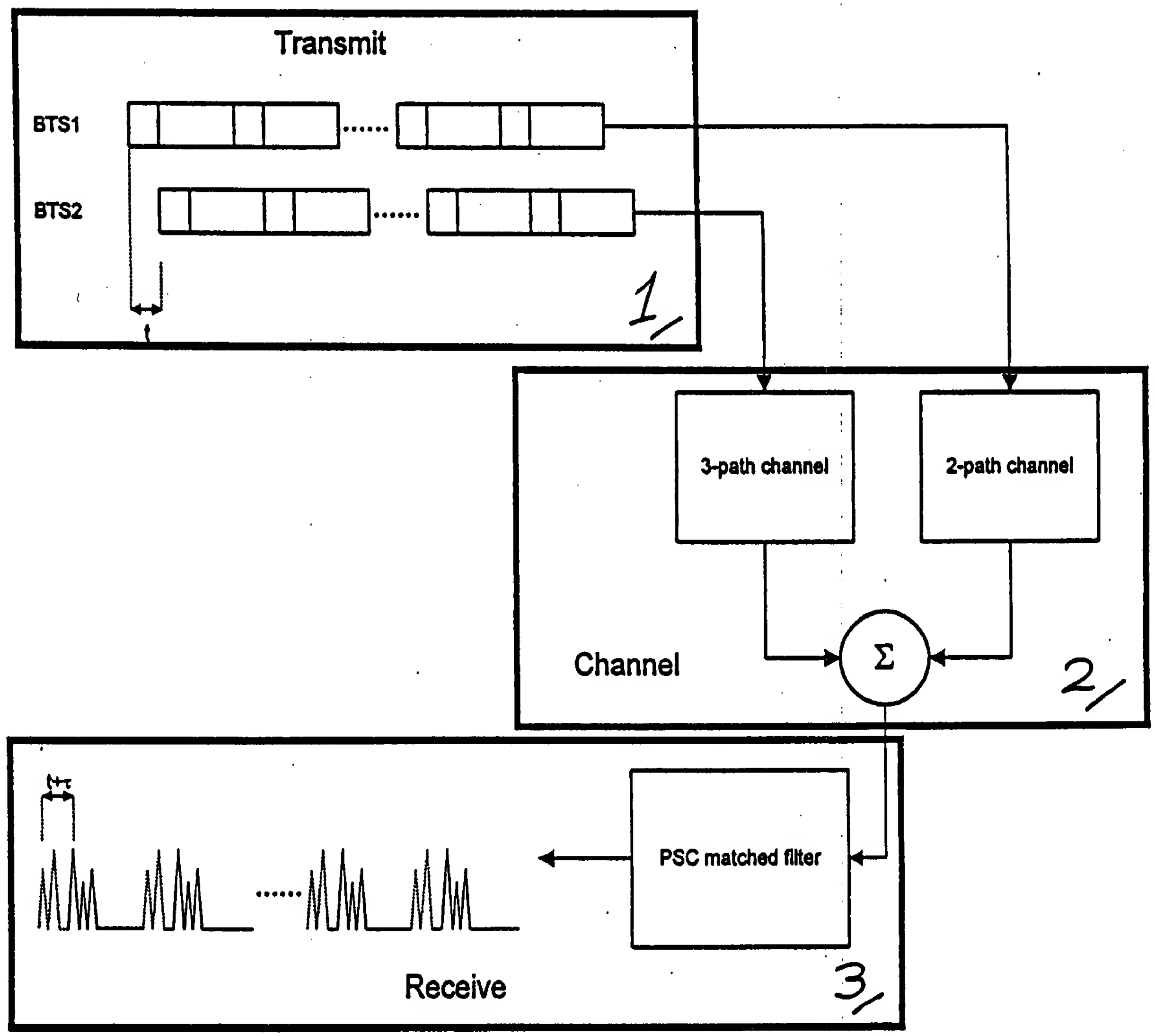
Transmit
BTS1
BTS2
1
3-path channel
2-path channel
Channel
Σ
2
PSC matched filter
Receive
3

Figure 1

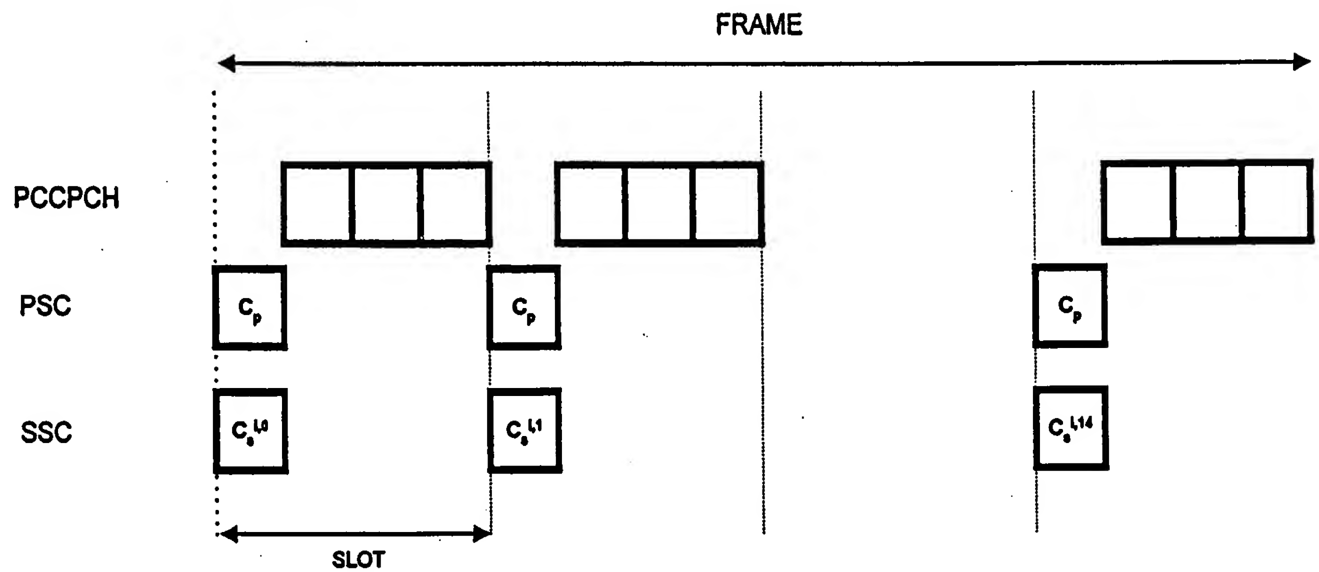


Figure 2

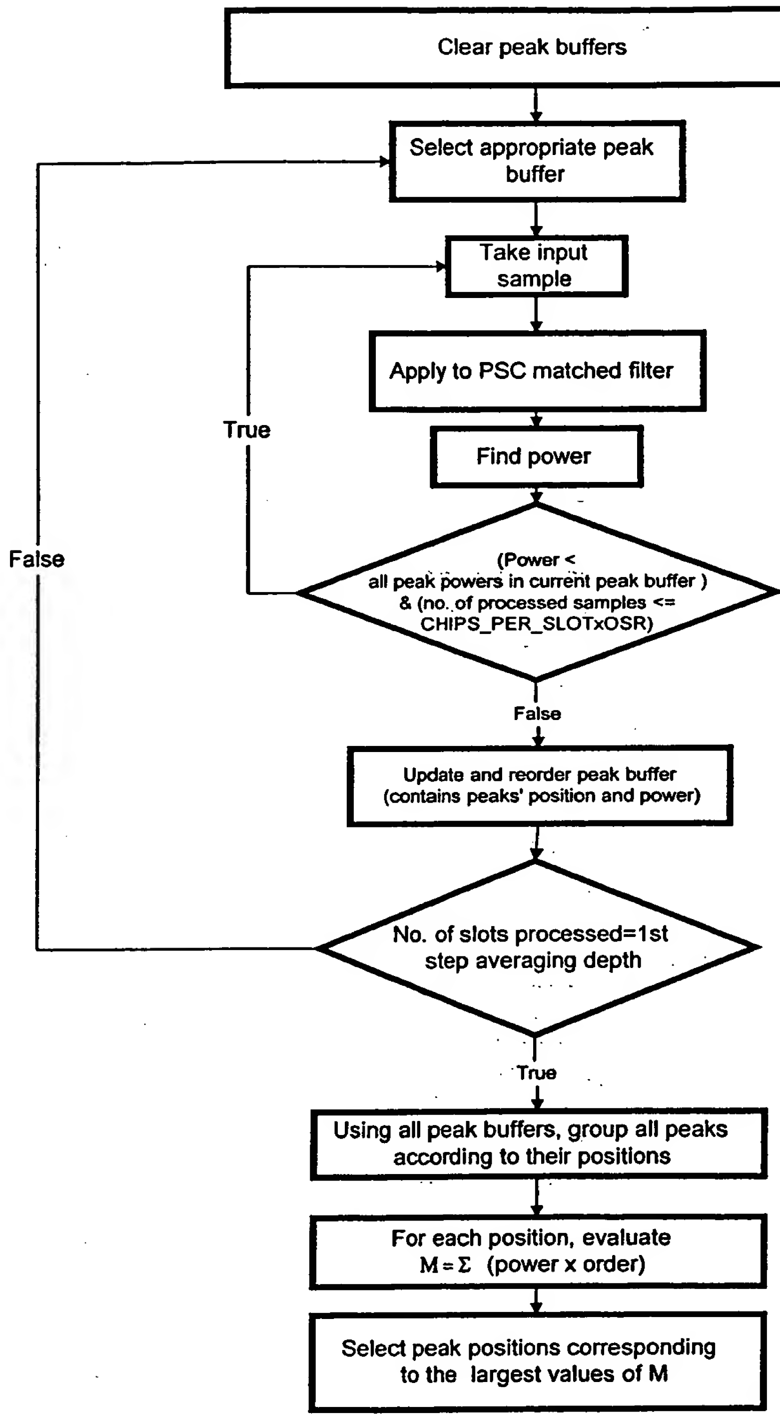
Clear peak buffers
Select appropriate peak buffer
Take input sample
Apply to PSC matched filter
Find power
(Power < all peak powers in current peak buffer ) & (no. of processed samples <= CHIPS_PER_SLOTxOSR)
True
False
Update and reorder peak buffer (contains peaks' position and power)
No. of slots processed=1st step averaging depth
False
True
Using all peak buffers, group all peaks according to their positions
For each position, evaluate M = Σ (power x order)
Select peak positions corresponding to the largest values of M

FIGURE 3

| | Largest peak (order, power, position) | 2nd largest peak (order, power, position) | 3rd largest peak (order, power, position) |
|---|---|---|---|
| 1st slot peak buffer | (3, 10.0, 2) | (2, 8.0, 100) | (1, 5.0, 20) |
| 2nd slot peak buffer | (3, 20.0, 2) | (2, 12.0, 50) | (1, 7.0, 100) |
| 3rd slot peak buffer | (3, 15.0, 10) | (2, 10.0, 2) | (1, 9.0, 50) |

**Table 1**

| | (order, power) information | M = (power x order) |
|---|---|---|
| Position 2 | (3, 10.0), (3, 20.0), (2, 10.0) | 110.0 |
| Position 10 | (3, 15.0) | 45.0 |
| Position 20 | (1, 5.0) | 5.0 |
| Position 50 | (2, 12.0), (1, 9.0) | 33.0 |
| Position 100 | (2, 8.0), (1, 7.0) | 23.0 |

**Table 2**

| | Largest peak - order, power, position, age_factor | 2nd largest peak - order, power, position, age_factor | 3rd largest peak - order, power, position, age_factor |
|---|---|---|---|
| 1st slot peak buffer | 3, 10.0, 2, 1.0 | 2, 8.0, 100,1.0 | 1, 5.0, 20,1.0 |
| 2nd slot peak buffer | 3, 20.0, 2,0.5 | 2, 12.0, 50,0.5 | 1, 7.0, 100,0.5 |
| 3rd slot peak buffer | 3, 15.0, 10,0.25 | 2, 10.0, 2,0.25 | 1, 9.0, 50,0.25 |

**Table 3a**

| | (order, power,age_factor) information | M = (power x rank) |
|---|---|---|
| Position 2 | (3, 10.0,1.0), (3, 20.0,0.5), (2, 10.0,0.25) | 65.0 |
| Position 10 | (3, 15.0,0.25) | 11.25 |
| Position 20 | (1, 5.0,1.0) | 5.0 |
| Position 50 | (2, 12.0,0.5), (1, 9.0,0.25) | 14.25 |
| Position 100 | (2, 8.0,1.0), (1, 7.0,0.5) | 19.5 |

**Table 3b**